LARP Collimation Program
Closing Remarks

08 April 2005
LARP Collaboration Meeting
Port Jefferson NY
Tom Markiewicz
SLAC

Task 1: Studies on a rotating metallic phase 2 collimator

Talks by: Ralph Assmann, Yunhai Cai, Lew Keller, Eric Doyle*

Task 2: Fast set-up and optimization of cleaning efficiency (simulations and tests at RHIC)

Talk by: A. Drees, BNL

Task 3: Improvements with tertiary collimators at the LHC experimental insertions

Talk by: N. Mokhov, FNAL

Task 4: Radiation tests of LHC collimator materials for phase 1 and phase 2 [new proposed work package]

Talk by: N. Simos, BNL

Program Planning

Contibutions & Discussions by all

Task #4: Radiation tests of LHC collimator materials

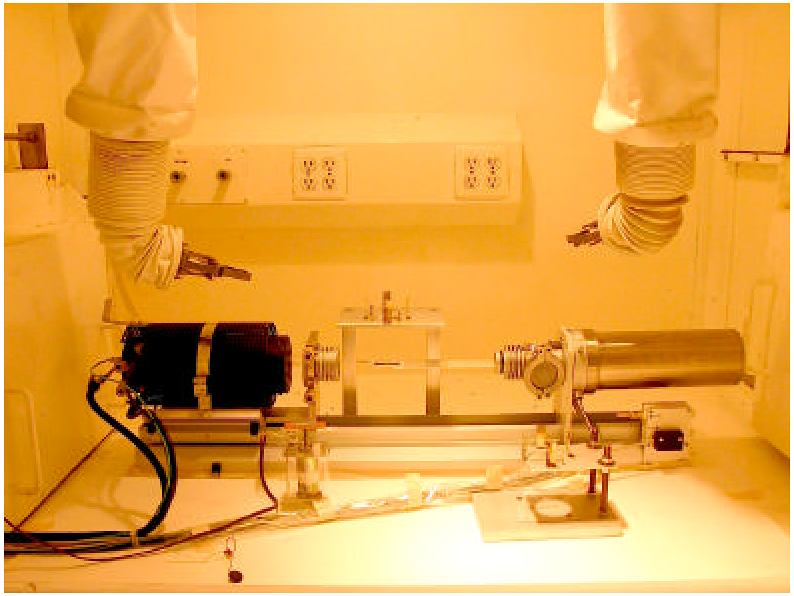
ASSESS the effects of proton irradiation on material properties

BNL AGS/BLIP/Hot Cell FACILITY

Properties: thermal expansion, mechanical properties, thermal conductivity/diffusivity and thermal shock

Materials: 2-d weave carbon-carbon and exact graphite used in phase I jaws plus materials considered viable for phase II jaws

Costs: Hot cell use fee, sample prep, apparatus improvement, postdoc



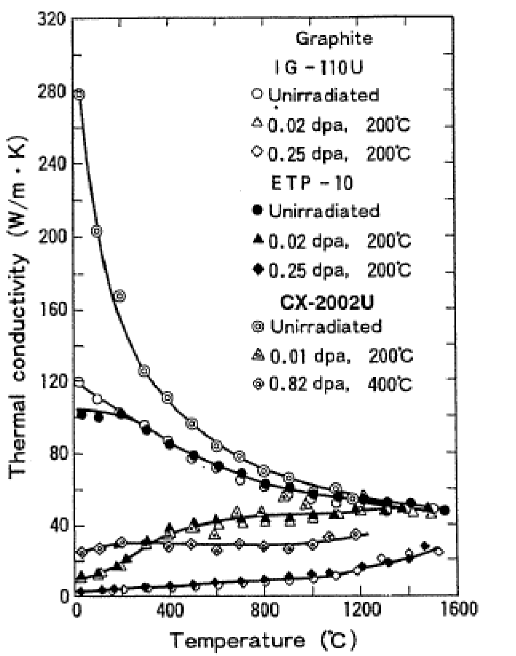
Should this program be added to LARP?

Graphite Properties Can Change Drastically After Irradiation

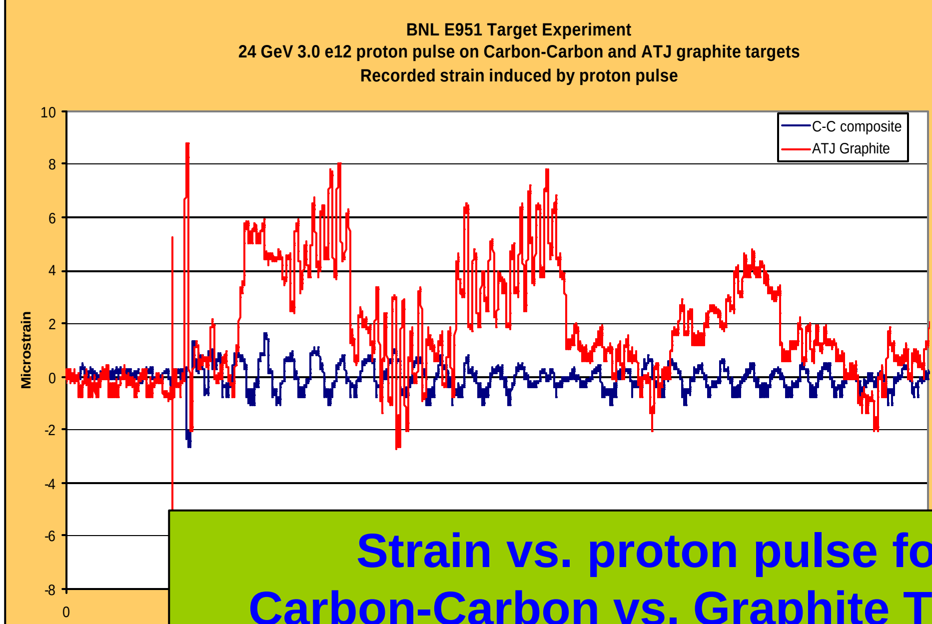
x10-30 Change in Thermal Conductivity after 0.25 dpa exposure

Thermal conductivity and dimensional change of neutron-irradiated graphites IG-110U, ETP-10 and GC-30

Irradiation	Thermal conductivity (W/(m K))			Dimensional change (%)		
	IG-110U	ETP-10	GC-30	IG-110U	ETP-10	GC-30
Unirradiated	119	101	16	–	–	–
0.02 dpa, 200°C	10.9	11.8	3.7	0.04	0.10	−0.14
0.25 dpa, 200°C	2.6	3.4	1.9	0.14	0.24	−0.68



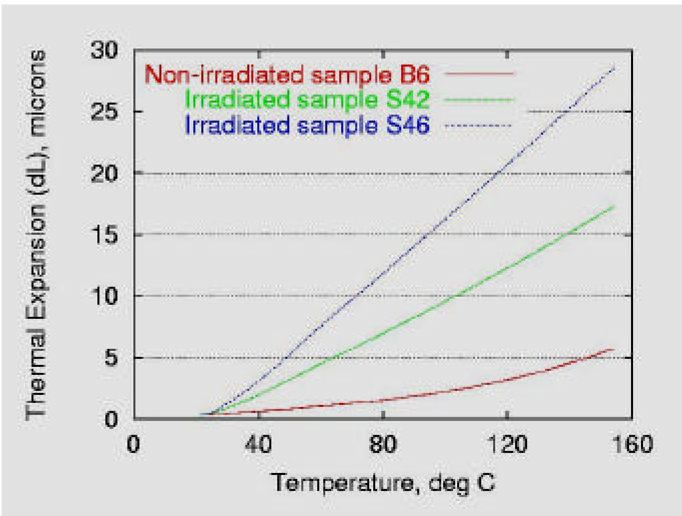
Thermal conductivity of neutron-irradiated graphites.

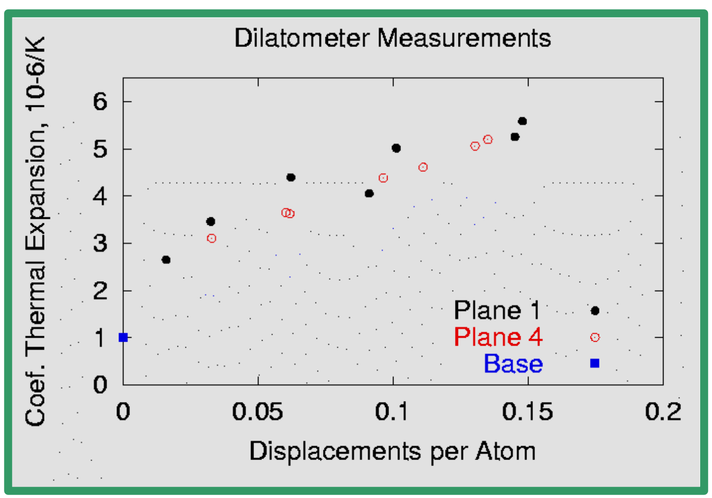


Strain vs. proton pulse for Carbon-Carbon vs. Graphite Targets

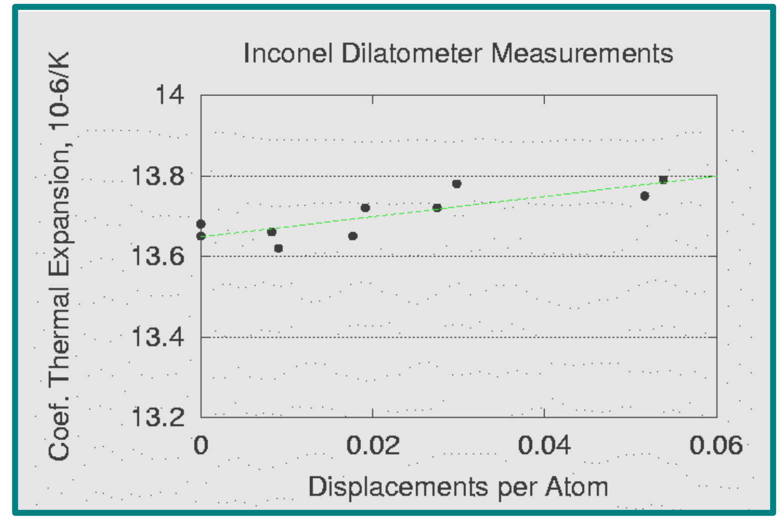
Variation of Properties of Possible Phase II Materials

INVAR

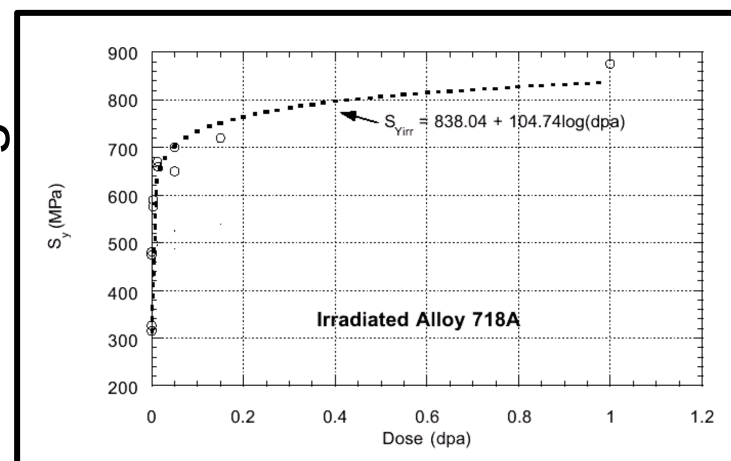




INCONEL

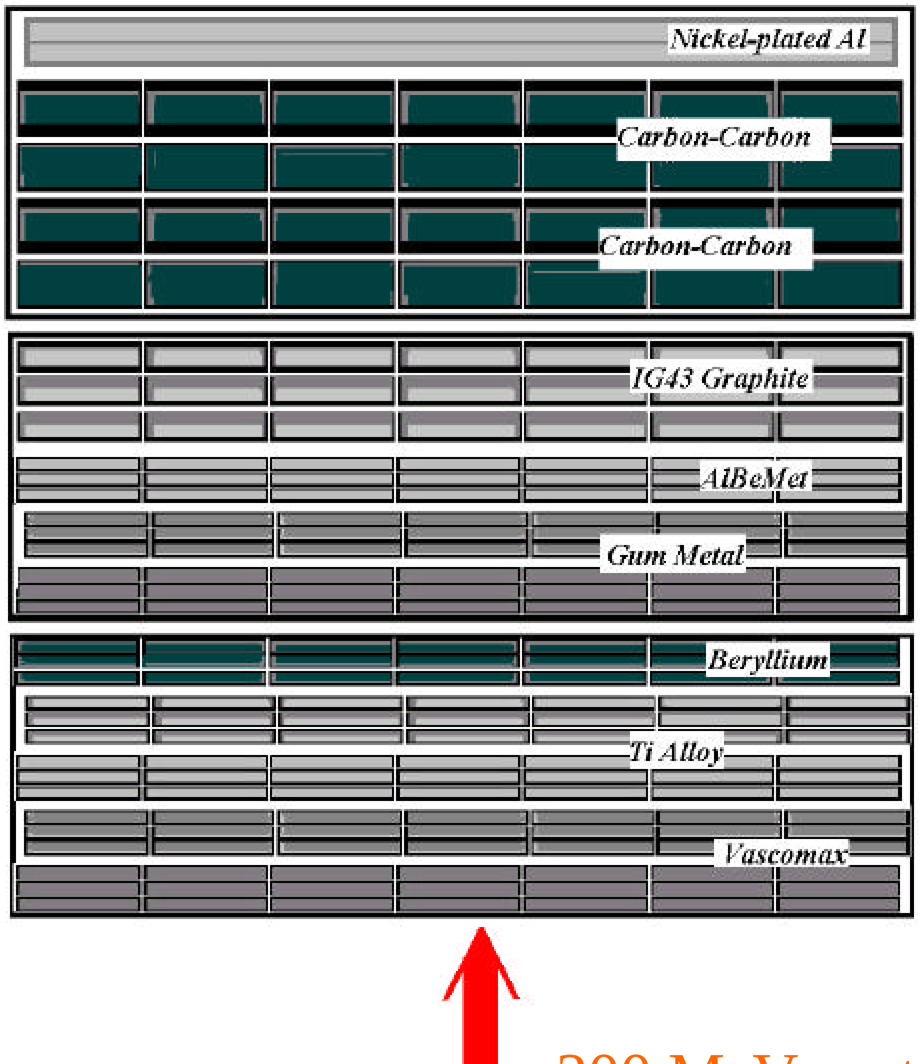


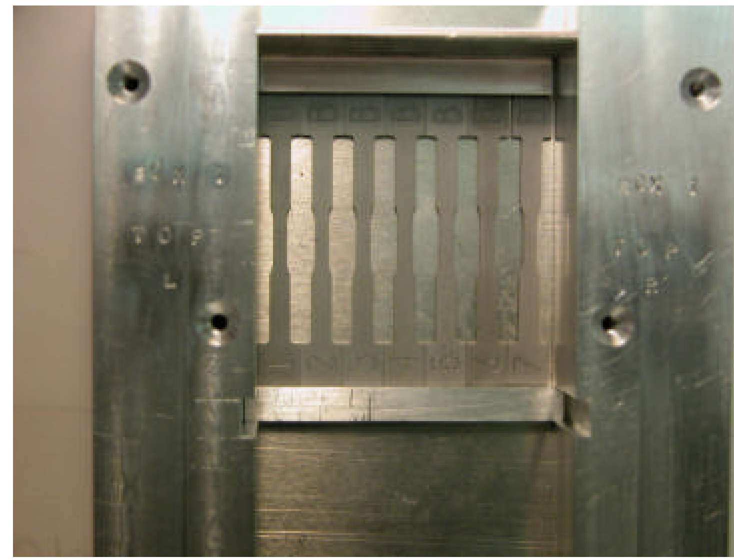
Yield Strength



Effect of irradiation in HFIR on the room-temperature yield strength of Alloy 718A

Current BNL Material Study





200 MeV protons (~70 μA)

Discussion of Radiation Test Proposal

Most published information is from low energy neutron irradiated

- This info will be transmitted to CERN
- little data from protons

Some information will be available based on Graphite & C-C samples already irradiated and to-be-studied

- Assess need to study exact materials used by CERN
    - **Samples will be obtained from vendor supplying CERN**
    - **Effort will be made to get them in to the upcoming BLIP run at BNL**

Plan for Phase II jaw material irradiation in FY2006

- Cu or exotic alloys

ALSO: ~ 1 cu.foot is available downstream of the Fermilab pbar target

- 120 GeV protons on target
- No facility use fee
- Materials would be transported to BNL & studied in hot cell facility

Begin now, end by end of FY07

Not exactly (%-wise) cheap after first "blue sky" discussion of budget needs yesterday

BNL:

- One LARP postdoc would be shared between this task and RHIC code benchmark / collimator setup task
- BLIP usage fees
- Sample measurement labor & measurement device upgrades

FNAL:

- Fractional FTEs of postdoc, physicist, technician

Discussions will continue, but given

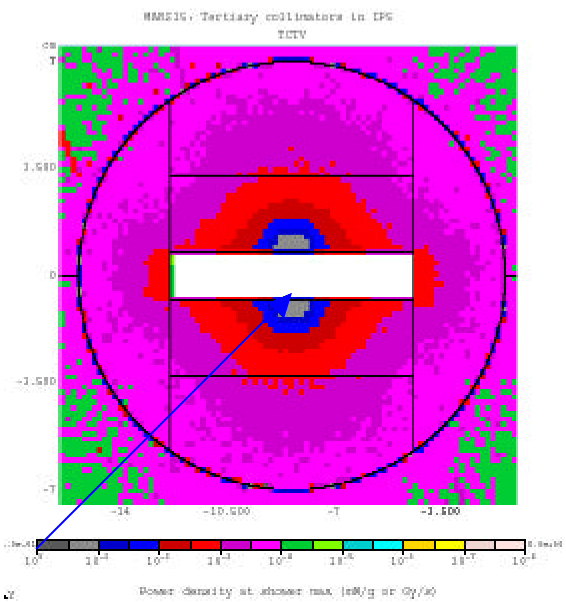
- Great interest by CERN & need to move quickly
- Funds-availability in 2005

Sense is that we **WILL** (at least) begin this task

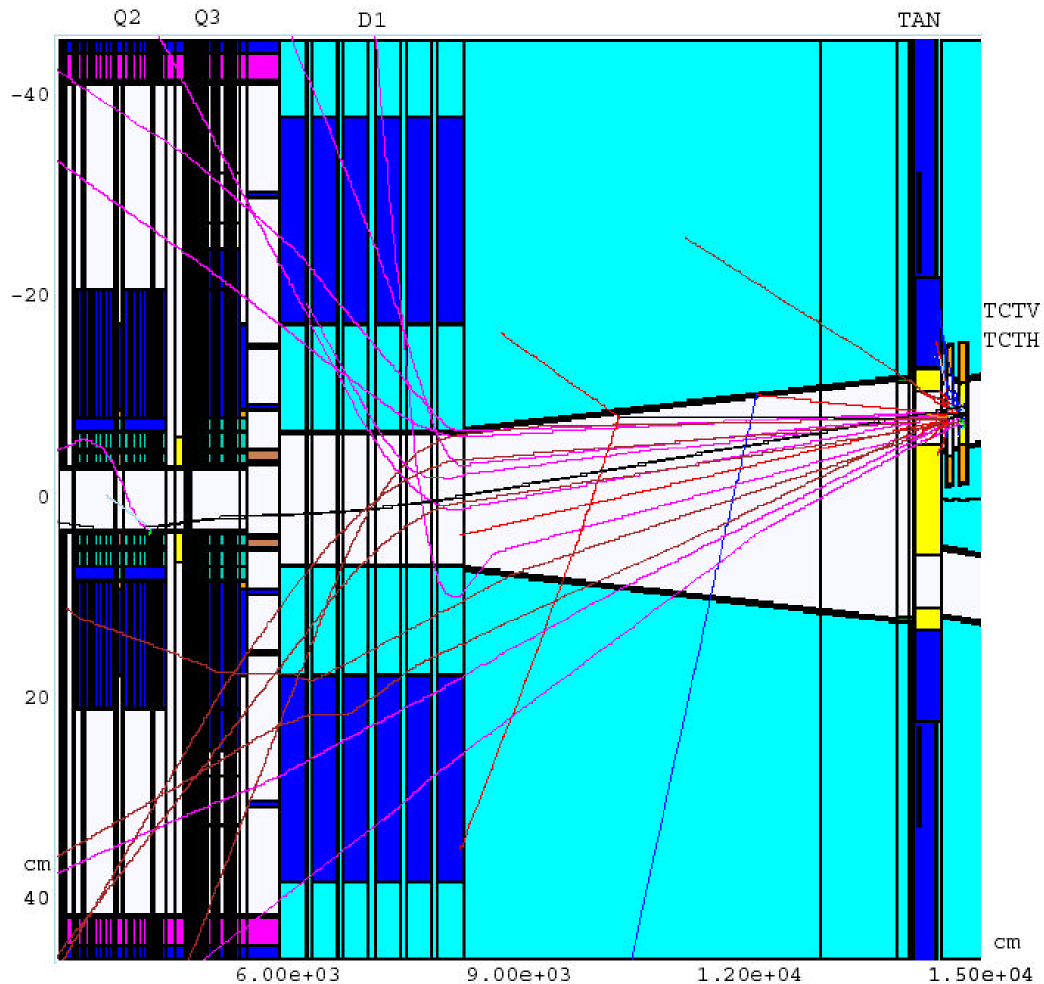
Task #3: Improvements with tertiary collimators at the LHC experimental insertions

Modeling in IP5 and CMS with tertiary collimators

1m Cu TCTV and TCTH @ z~150m
25mm x 80mm jaws @ 8.4s

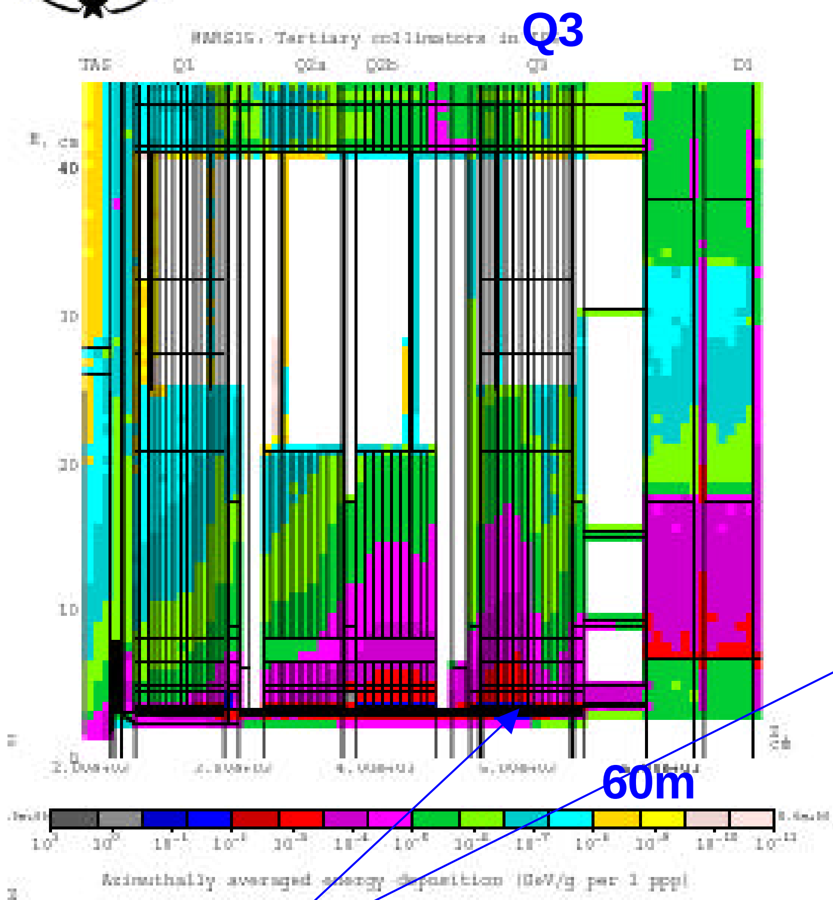


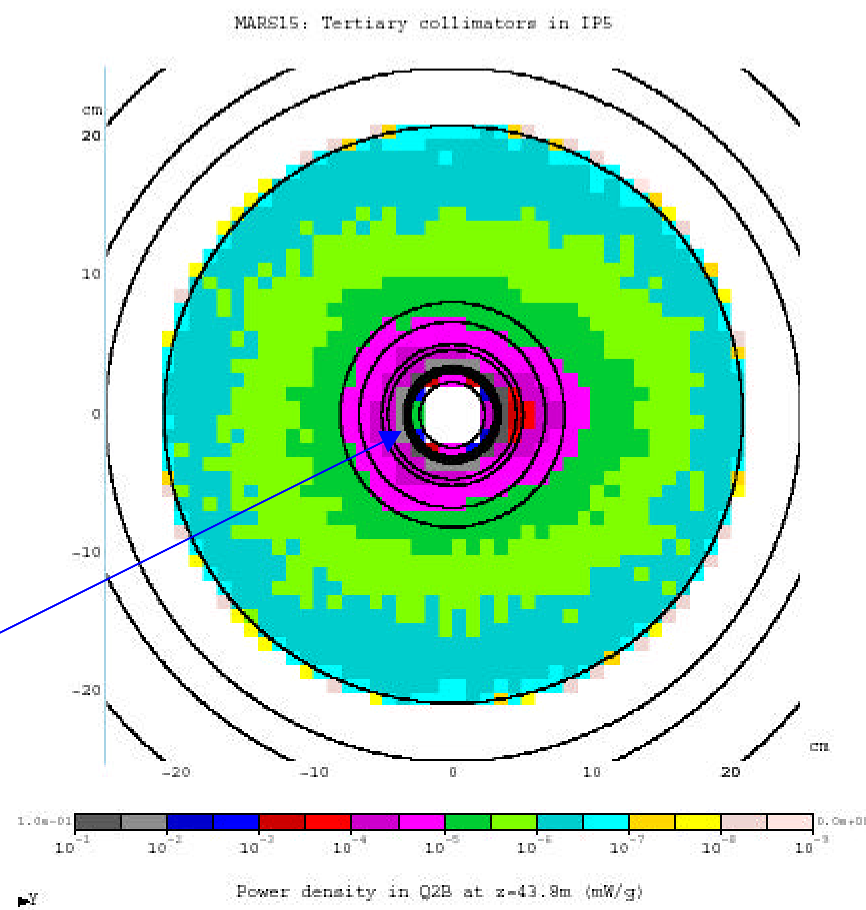
1mW/gm @ 10^6 p/s



150m

TCT-Induced Energy Deposition in Triplet Quads



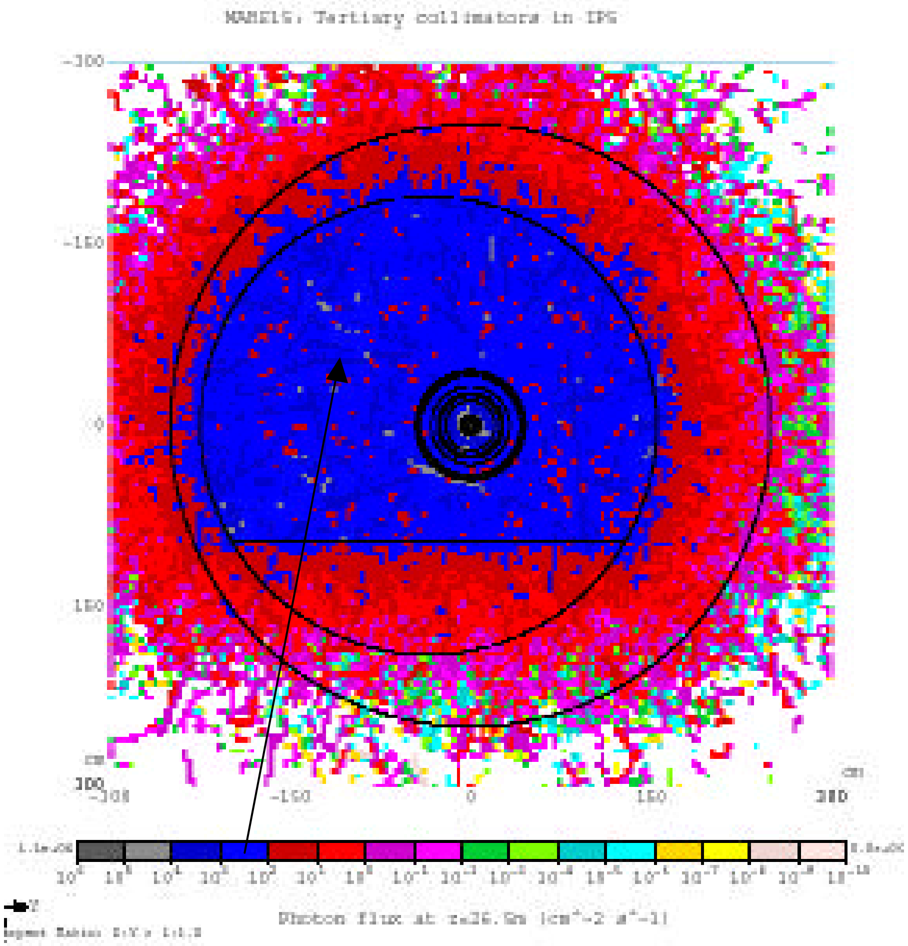


Peak Energy deposition of 0.35mW/g in Q3 SC coils at b_{MAX} @ z~50m @ 10^6 p/s

Design spec of DQ<0.53mW/gm ® max loss rate at TCT ~ 2 x 10^6 p/s

TCT-Induced Particle Flux entering Detector @ z=26.5m

Photon Flux



~1000 photons/cm2/s @ 10^6 p/s scraped ~ physics backgrounds

Immediate Tasks

- **Determine Efficiency of TCT**
- **Relative performance of W vs. Cu**

Longer Range:

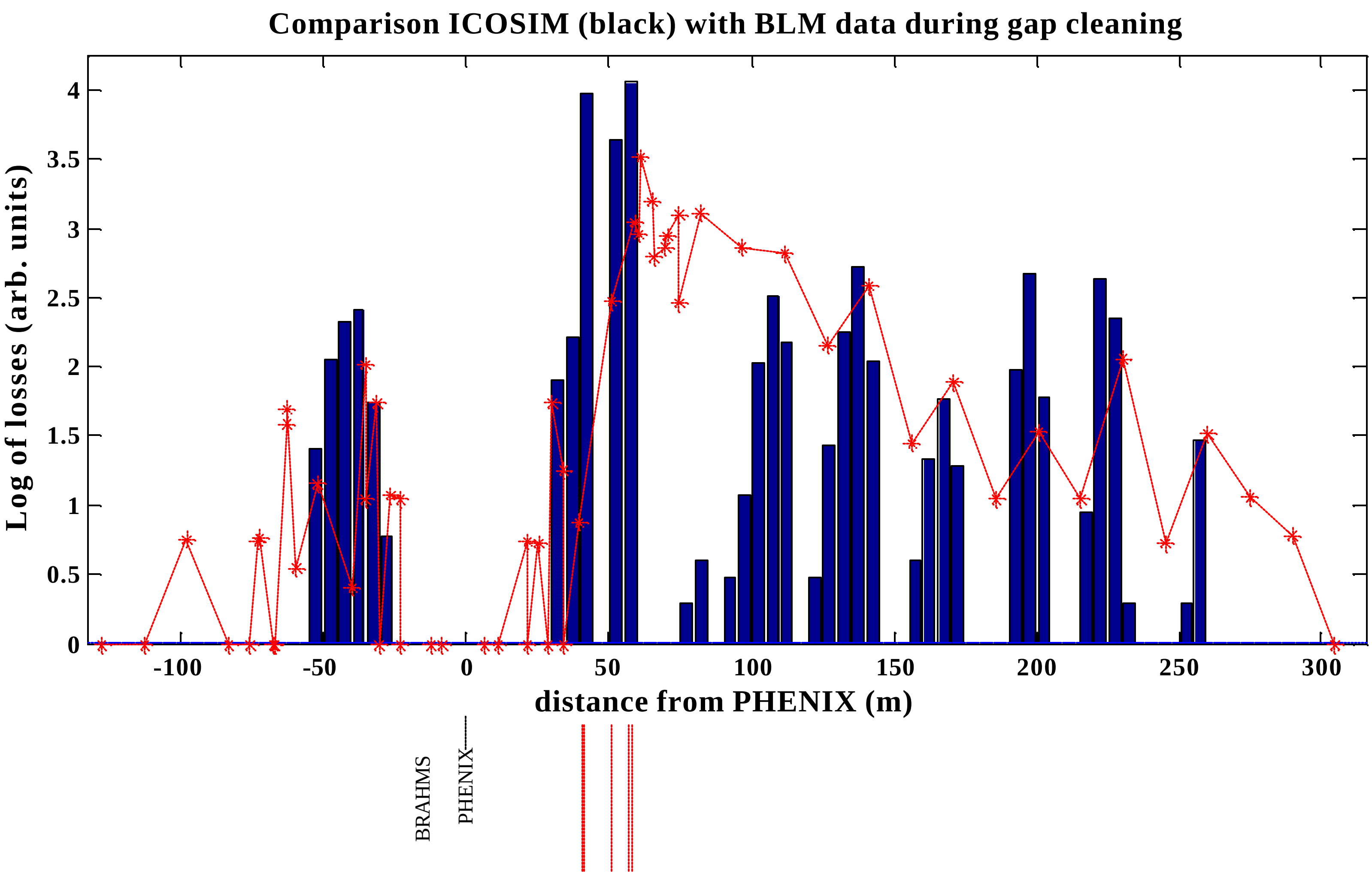
- **Engineering Studies**
- **Accident Studies**
- **More realistic Halo**
- **Sensitivity studies**

Task #2:Ion Loss Simulations Benchmarked at RHIC

Benchmarking of ICOSIM with RHIC HI data

- Beam Loss Monitor Data from abort gap cleaning during a physics run
  - More data with better controlled conditions i.e. loss maps with only one collimator in and all others out, are available now for Cu
- ICOSIM a simpler code than SIXTRACK
  - Data analysis by H. Braun (CERN)
  - Import code to BNL for the short term
  - Merge ion specific parts of code with SIXTRACK
- Reasonable agreement observed
  - As Ions typically do NOT make multiple turns around ring

Reasonable Agreement for Ions

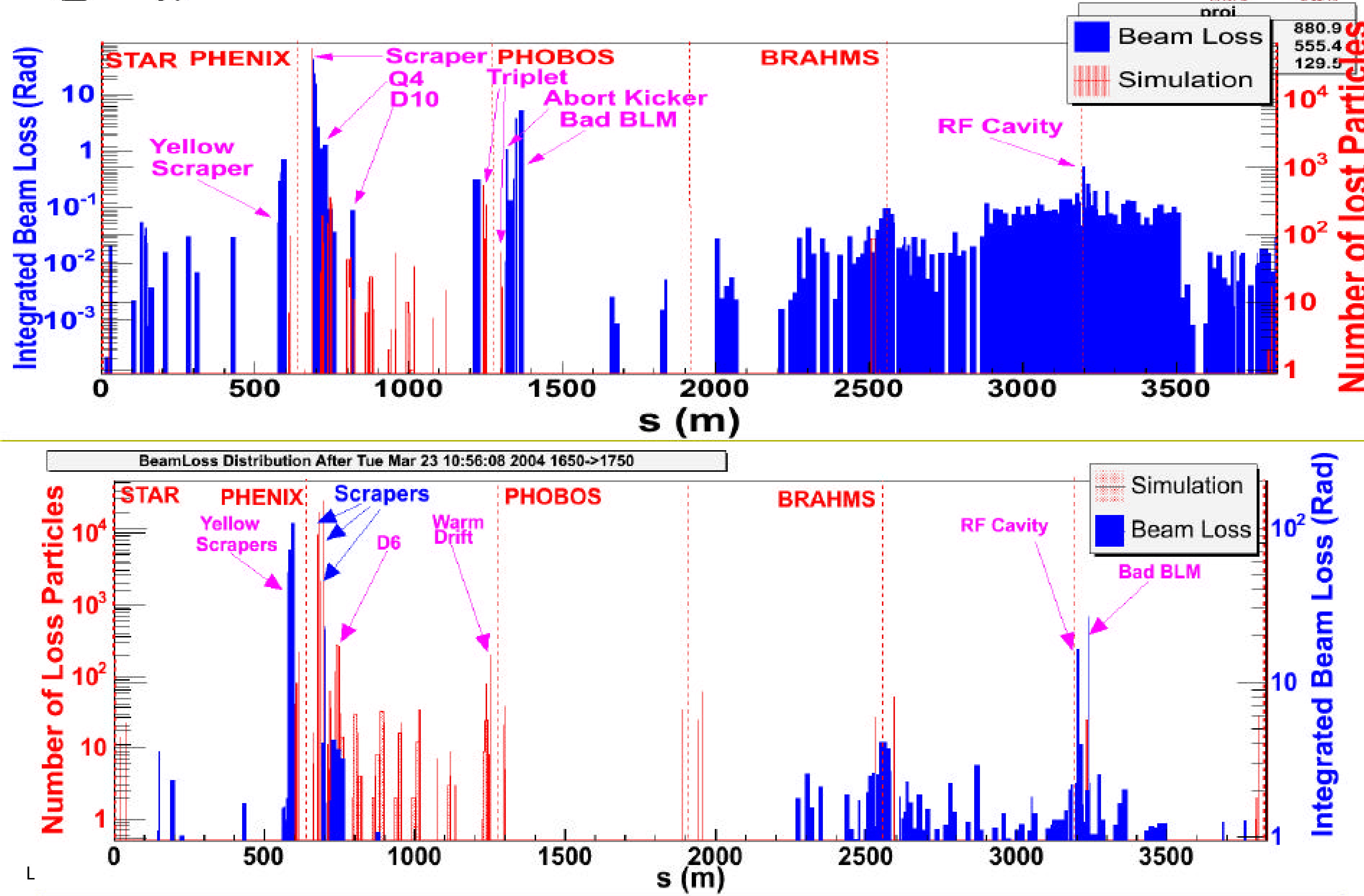


Task #2:Proton Loss Simulations Benchmarked at RHIC

Benchmarking Tracking Codes w/ RHIC Proton data

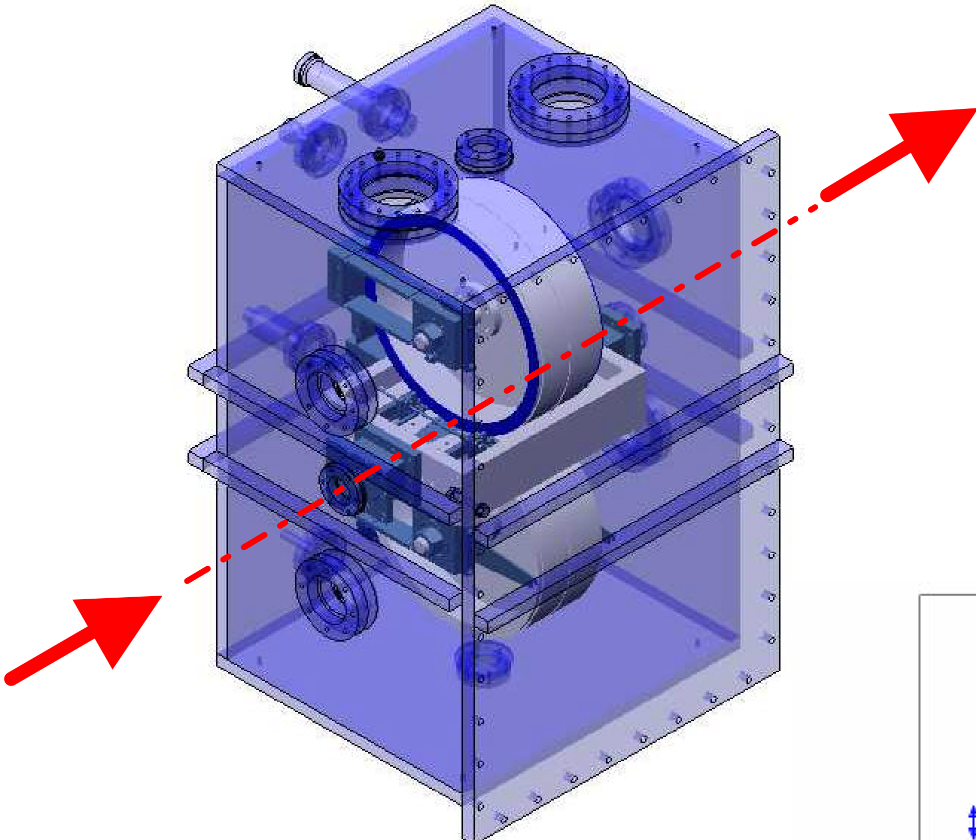
- Beam Loss Monitor Data from log files during a physics run
  - Devoted data with better controlled conditions needed & will be taken during current run
- Existing simulations from “Teapot” & “K2” codes, with known problems
  - Agreement poor
    - Multi-turn tracking more challenging
  - SIXTRACK code installed for some time
    - Needs updating & RHIC lattice installed
      - (CERN help coming soon)
- Postdoc search still ongoing
  - To be “shared” with radiation exposure test program

Poor Agreement for p running with either 1-stage(upper plot) or 2-stage (lower plot) collimation systems



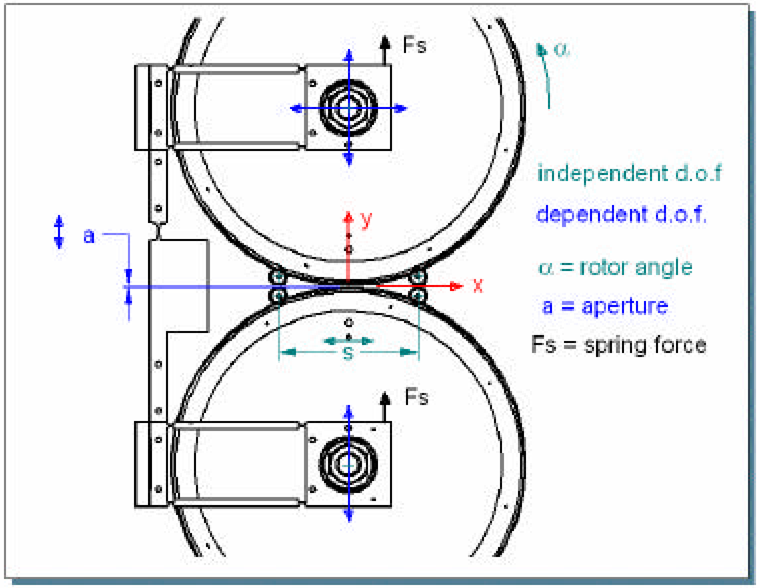
L

Reminder of SLAC NLC “Consumable Spoiler” as Prototype for Phase II LHC Secondary Collimator



Differences LC / LHC:

- **Jaw length**
- **Maximum gap &**
- **Power deposited**

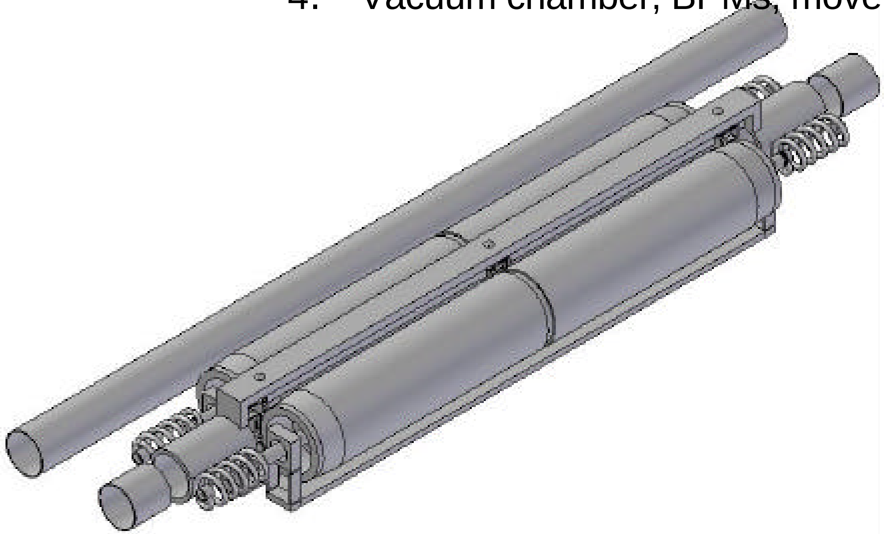


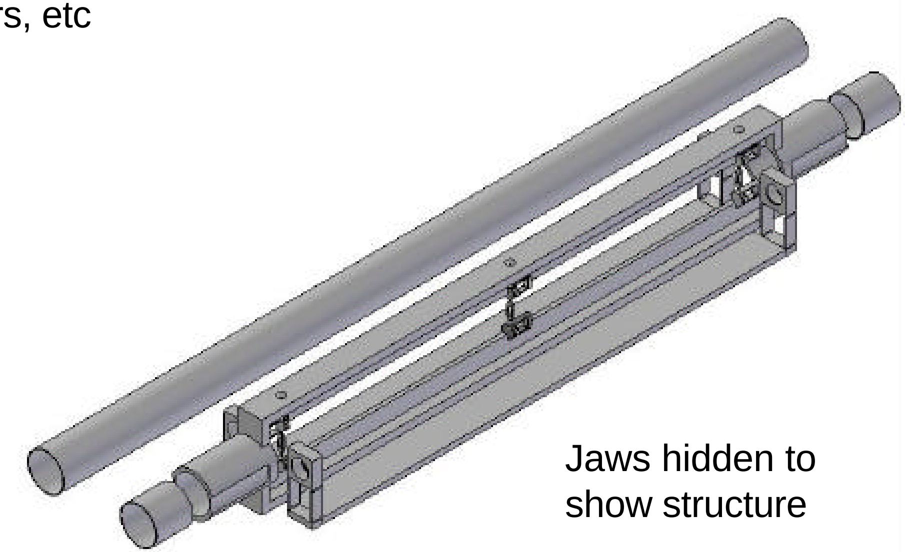
LHC Collimator Mechanism Concept

End and center aperture stops included in same model

Note: Conceptual model. Not much detail engineering yet. Not included:

1. Rotary jaw indexing mechanism
2. Loading springs which hold jaws against aperture stops
3. Open aperture power-off mechanism
4. Vacuum chamber, BPMs, movers, etc

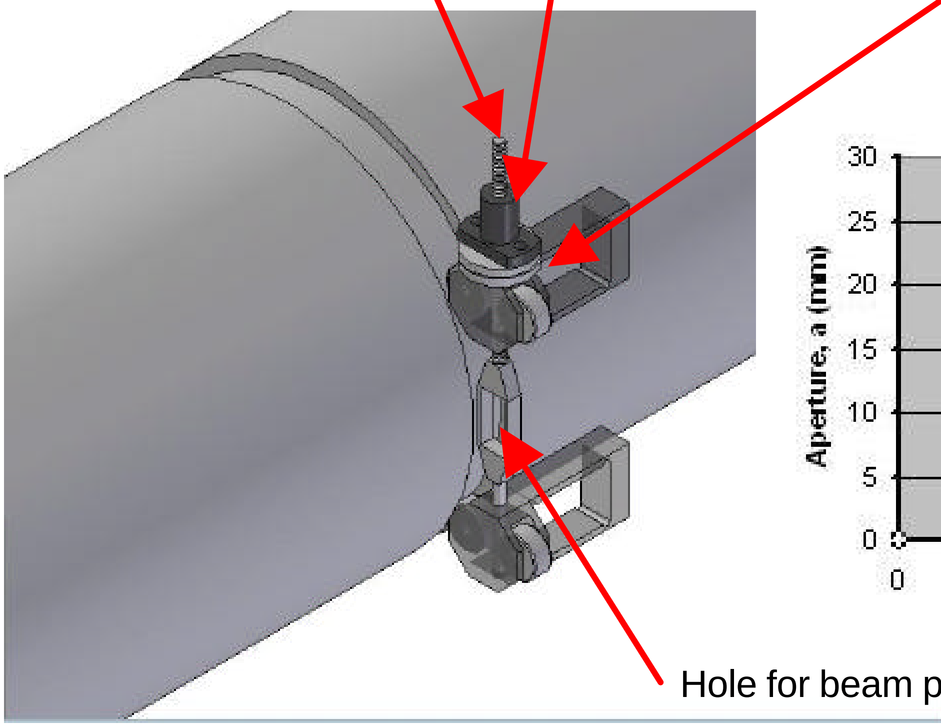


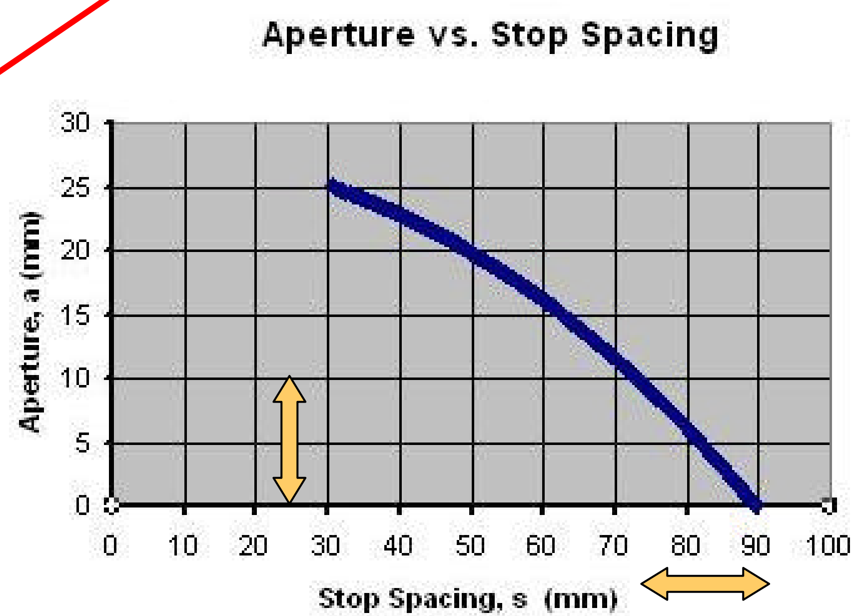


Jaws hidden to show structure

- 1.2m long jaws
- Helical coolant supply tubes flex, allow one rev of jaw
- Jaws supported a both ends for stability, allow tilt control
- Alternative: jaws supported in center
  - thermal deflection away from beam
  - no tilt control

Stop Roller Details

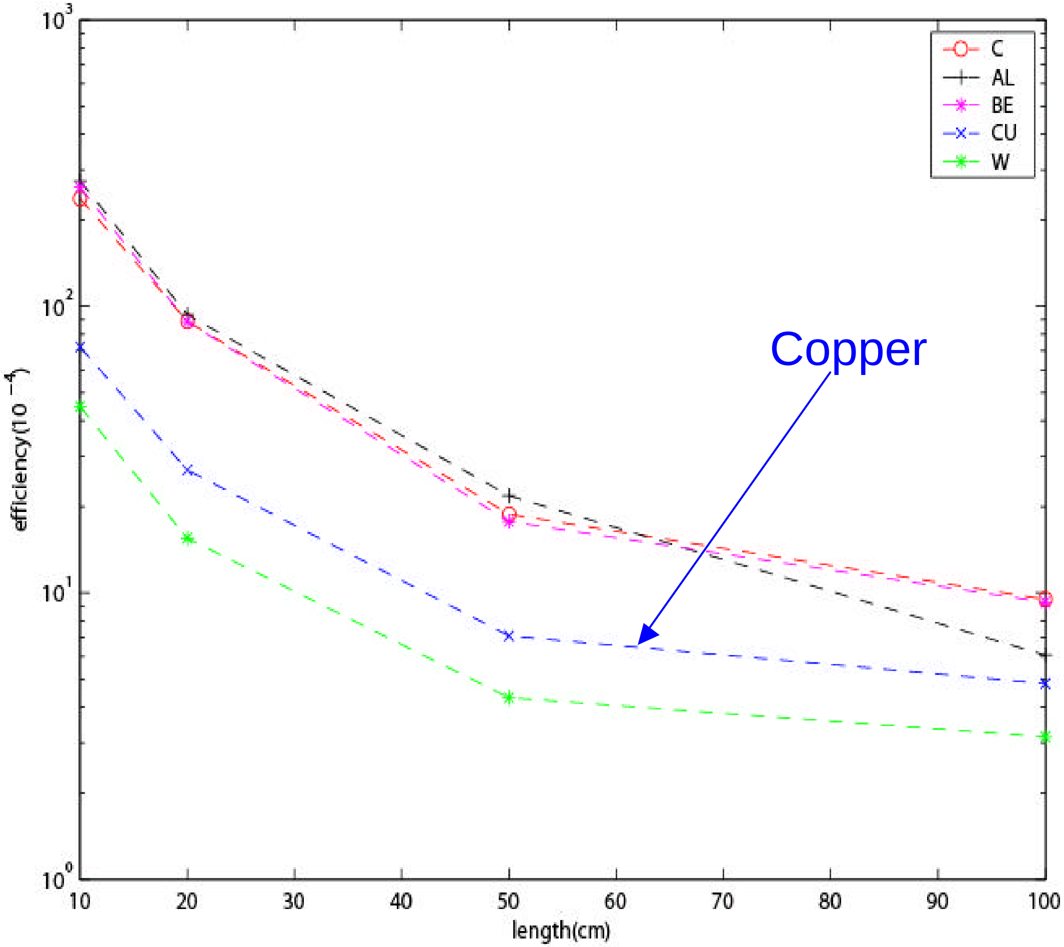




As shown in current model: aperture range limited to ~ 10mm. This can be improved but this mechanism will not be able to produce the full 60mm aperture. Auxiliary jaw retracting mechanism needed. Also note possible vulnerability of mechanism to beam-induced heating.

Study of Material for Secondary Collimators

Yunhai Cai



Heavy material is more effective in terms of efficiency of the system. So copper is chosen because its high thermal conductivity.

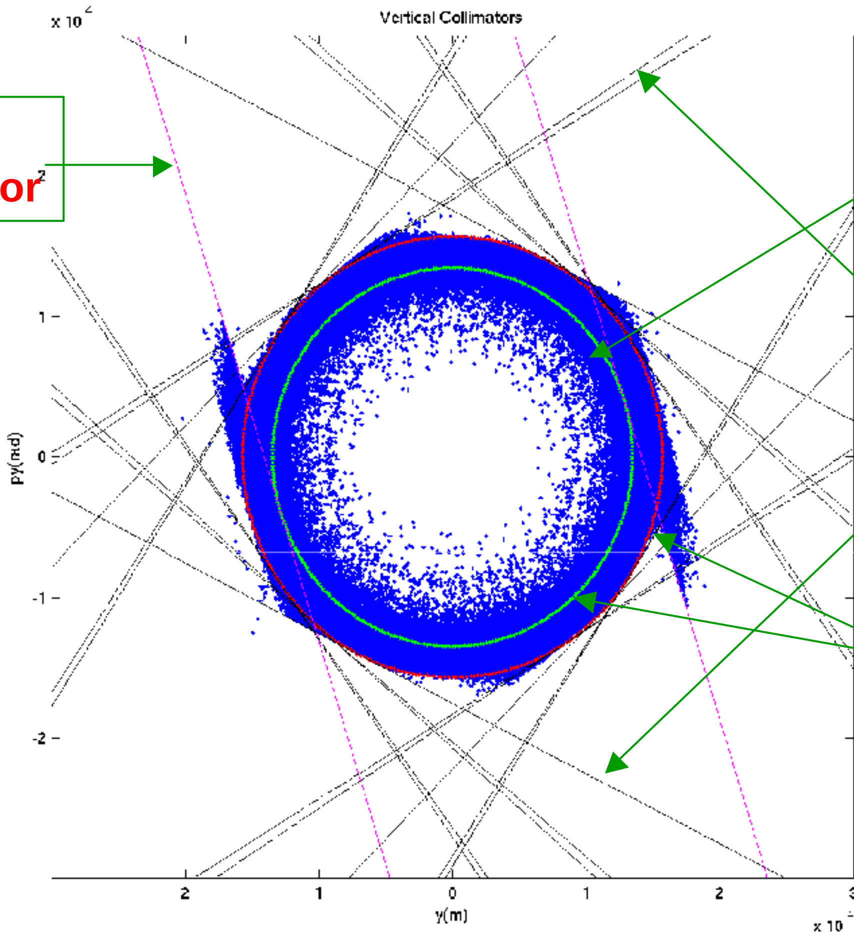
Length should be about 1 meter.

Achievable efficiency is about 3.5×10^{-4} at 10 σ.

Similar result was obtained by Ralph Aβmann

Vertical & Skew Collimators

Primary collimator



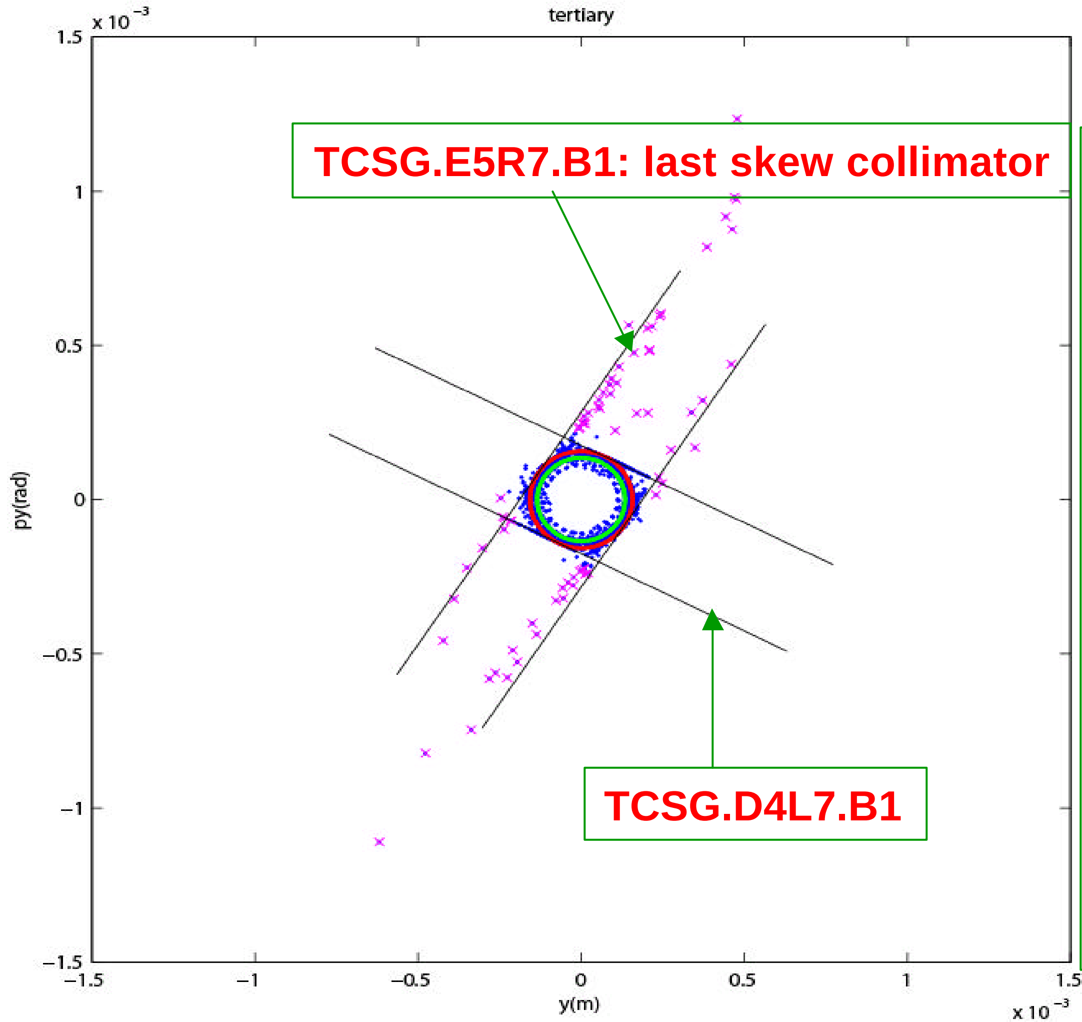
Secondary halo in normalized phase space at the end of collimation system

Collimators are projected to The end of collimation system

6 and 7 sigma contours

This is an independent check of the simulation code, since the collimators are plotted according to the lattice functions calculated using MAD.

Tertiary Halo: Particles Escaped from the Secondary Collimators

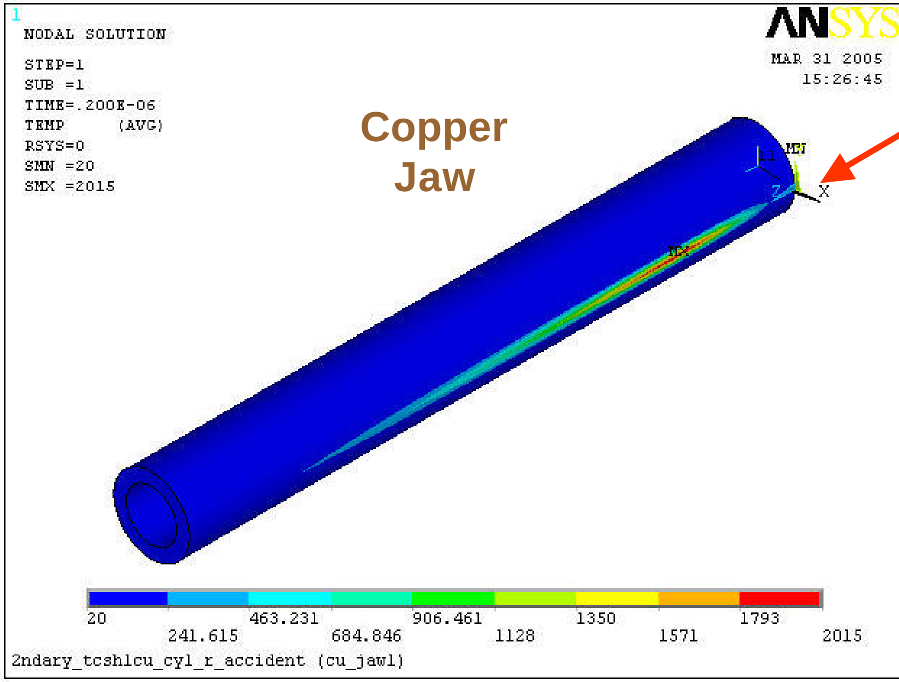


Number of particles beyond 10σ is 73, which is consistent with the efficiency calculation: 73/144446 = 5x10^{-4}.

Tertiary halo at large amplitude is generated by the large-angle Coulomb scattering in the last collimator.

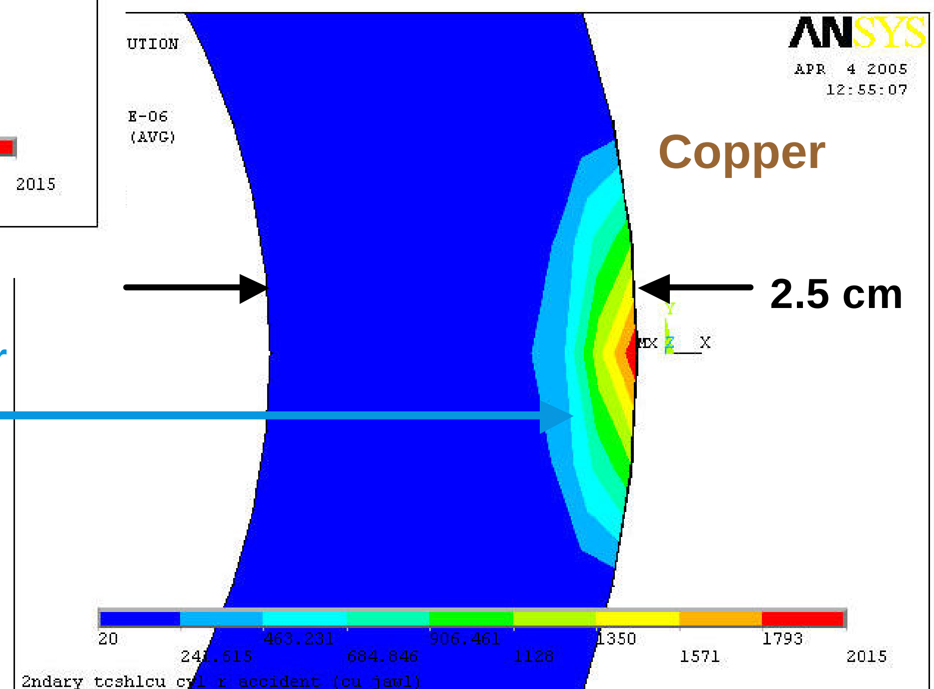
If we add a tertiary collimator at 8σ in the same phase as the collimator: TCSG.D4L7.B1 after the secondary collimators, the efficiency should be better than 1x10^{-4}.

What is the damage area in a missteering accident?



Missteered beam (9E11 protons) on secondary Jaw

Cross section at shower max.



Fracture temp. of copper is about 200 deg C

Assumed Damage threshold seems inconsistent with FNAL experience

Power Deposition on First Secondary Collimator in 12 Min. Lifetime
(kW per jaw)

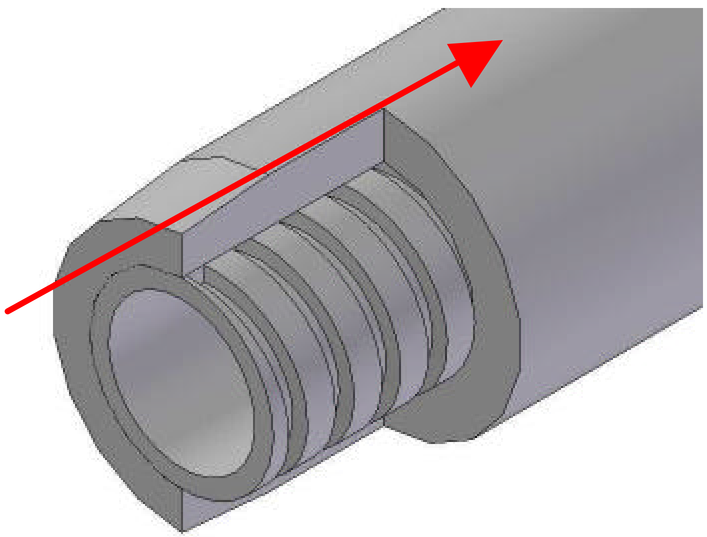
Sensitivity to aperture and to source of halo: H, V, or S

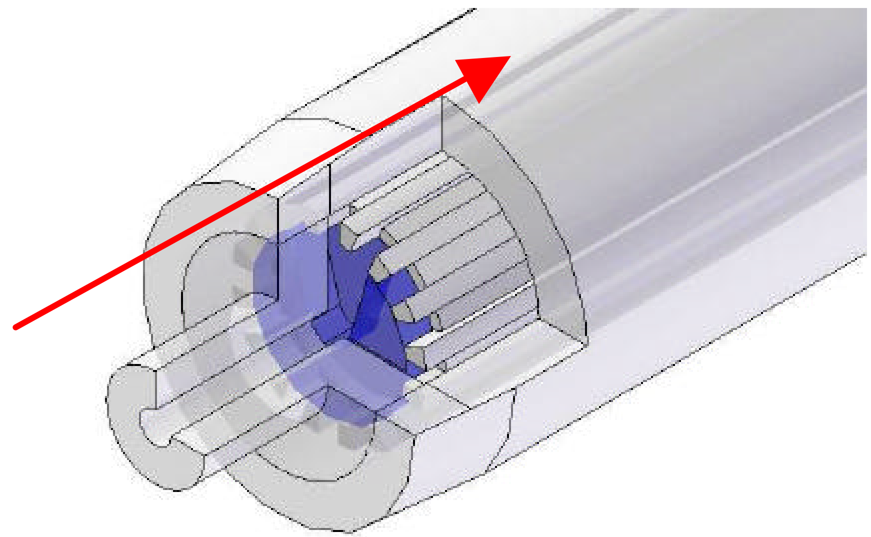
Primary Collimator (source)	TCSM.B6.L7 Jaws at 7 sigma		TCSM.B6.L7 Jaws at 10 sigma	
	Copper	Al_2219	Copper	Al_2219
TCP.D6.L7 (TCPV)	73	26	51	19
TCP.C6.L7 (TCPH)	61	22	49	19
TCP.B6.L7 (TCPS)	92	28	56	20

Notes:

1. Collimator data, ray files, and loss maps from LHC Collimator web page, Feb. 2005.
2. Must add contribution from direct hits on secondary jaws.

360º & limited arc coolant channel concepts



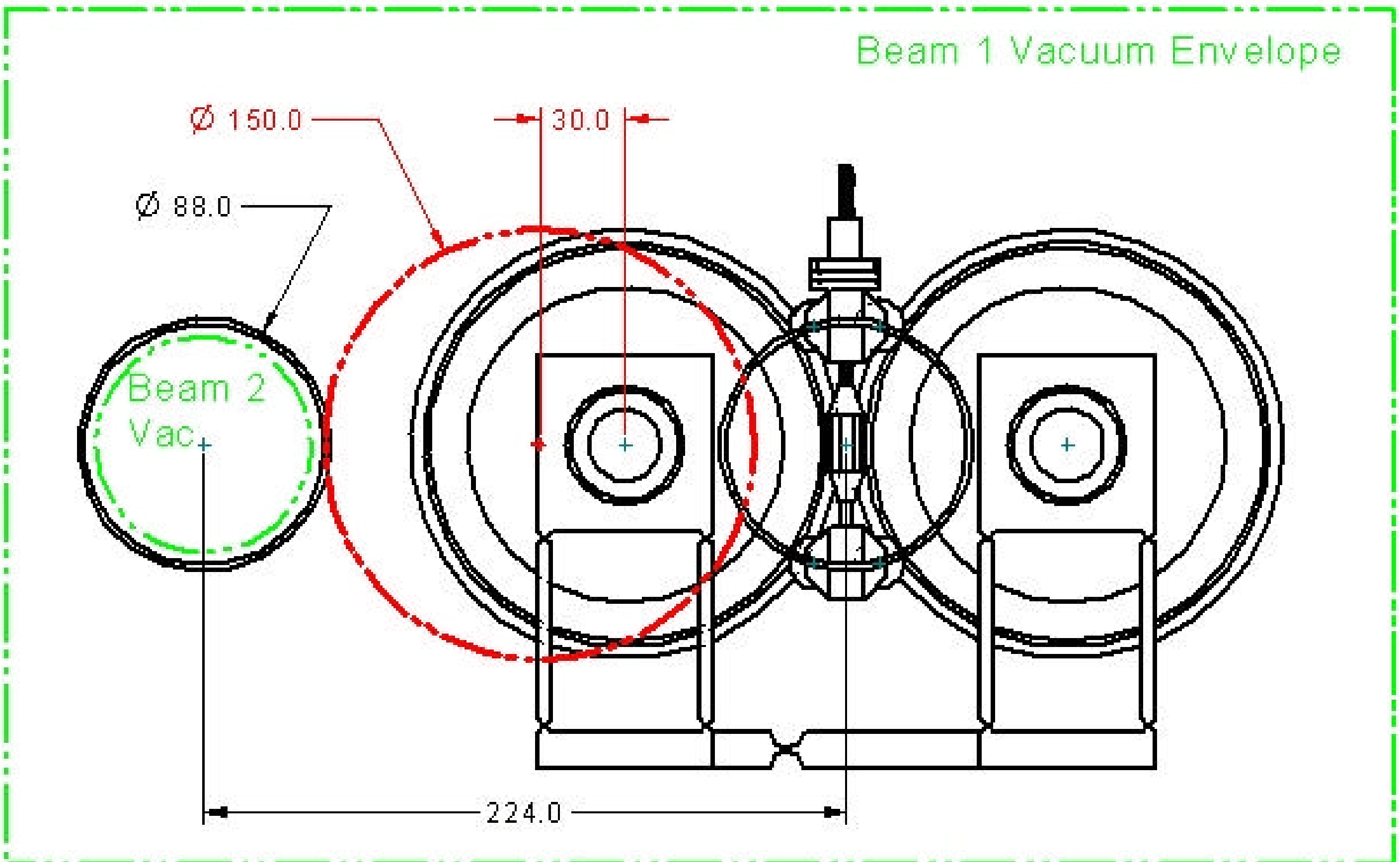


360º cooling by means of a helical channel. Lowers peak temperatures but, by cooling back side of jaw, increases net ΔT through the jaw, and therefore thermal distortion. Could use axial channels.

Limited cooling arc: free wheeling distributor – orientation controlled by gravity – directs flow to beam-side axial channels regardless of jaw angular orientation. Far side not cooled, reducing ΔT and thermal distortion.

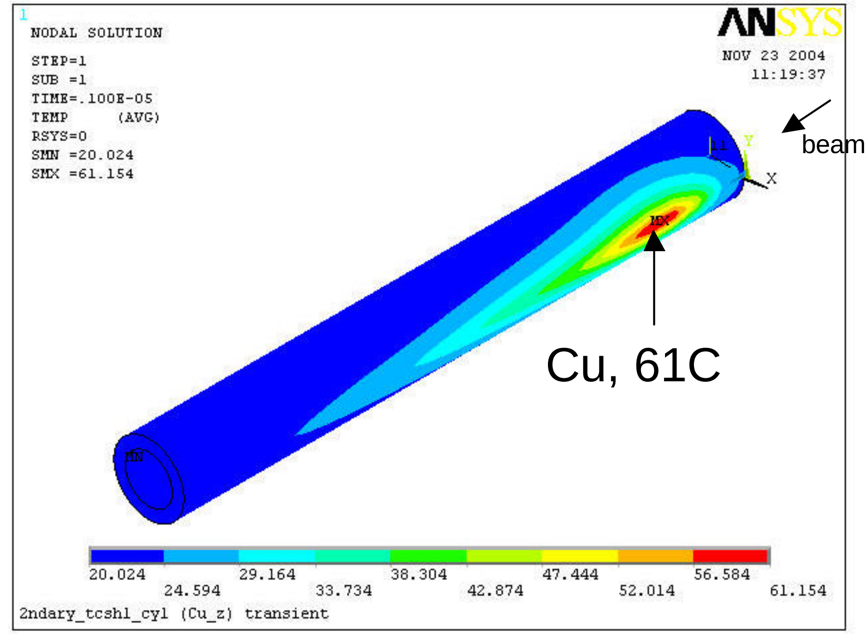
Geometrical limits due to 150mm rotor, 224 mm Beam Axis Spacing, 8.8cm beam pipe

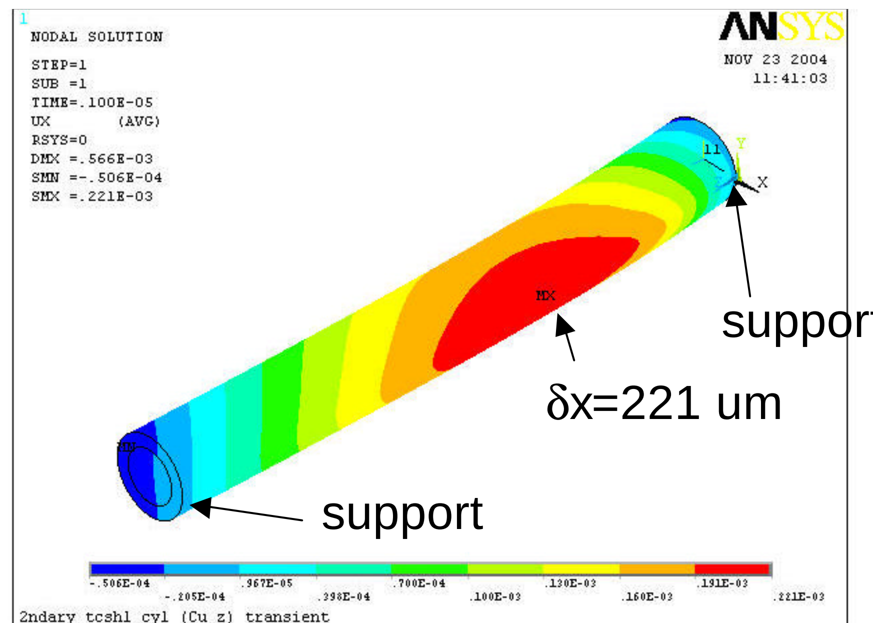
30mm jaw travel (in red) causes jaw to intersect adjacent beam pipe. No space for vacuum chamber wall. Resolution: 1) smaller jaw diameter 2) vacuum envelope encloses adjacent beam pipe 3) less jaw motion 4) reduce diameter of adjacent beam pipe.



3D Time Dependent Thermal Distortion Simulations

- 150mm OD, 25mm wall, 1.2m long
- Simply supported
- ANSYS simulation: FLUKA energy deposit for 10x10x24 rectangular grid mapped to similar area of cylinder
- Most cases: TCSH1 receives 80% of debris from primary (TCPV) plus 2.5% of direct beam per jaw. TCSH1 at 10σ.
- Steady state: 1hr beam lifetime
- Transient:10 sec @ 12 min beam lifetime
- I.D. water-cooled 20C, h=11880 W/m^2/C
    - -Temperature rise of H_2O not modeled
- Materials: Al, 2219 Al, Be+Cu, Cu, Invar, Inconel
    - -Ti, W rejected based on 2-D analysis
- Variations
    - - 45^o of ID nearest to beam cooled (not whole 360^o)
    - - solid cylinder (not thick wall) 45^o cooled





Material Comparison for SS & Transient Thermal Deflection: LHC Spec. is 25um

primary debris + 5% direct hits		SS @ 1 hour beam life			transient 10 sec @ 12 min beam		
material	cooling arc (deg)	power (kW) per jaw	Tmax (C)	defl (um)	power (kW)	Tmax (C)	defl (um)
BeCu (94:6)	360	0.85	24	20	4.3	41	95
Cu	360	10.4	61	221	52	195	829
Cu - 5mm	360	4.5	42	117	22.4	129	586
Cu/Be (5mm/20mm)	360	5.3	53	161			
Super Invar	360	10.8	866	152			
Inconel 718	360	10.8	790	1039			
Al	360	3.7	33	143			
2219 Al	360	4.6	34	149	23	79	559
C R4550	360	0.6	25	5	3.0	41	20
BeCu (94:6)	90	0.85	25	8	4.3	41	86
BeCu (94:6)	45	0.85	27	2	4.3	46	101
Cu	45	10.4	89	79	52	228	739
Cu - solid	45	10.4	85	60	52	213	542
2219 Al	45	4.6	43	31	23	89	492

Notes:
1. BeCu is a made-up alloy with 6% Cu. We believe it could be made if warranted
2. 2219 Al is an alloy containing 6% Cu
3. Cu/Be is a bimetallic jaw consisting of a 5mm Cu outer layer and a 20mm Be inner layer
4. Cu – 5 mm is a thin walled Cu jaw
5. Super Invar loses its low CTE above 200C, so the 152um deflectio n is not valid
6. Green shading: meet our suggested alternative spec of 50um for SS and 200um (1σ) for the transient.

Technical Discussions of Phase I Project

- Only low Z, Be compounds, absorb sufficiently little energy, conduct the heat away fast enough, and are stiff enough to come close to meeting jaw straightness tolerance of 25um
- Deflection of jaw away from beam of collimators immediately downstream of primaries (hardest hit) may be allowed if sufficiently low and overall collimation efficiency maintained by remaining collimators
- Be, C, and Al do not provide adequate cleaning efficiency
- Shorter 50cm collimators not excluded (at least in hard hit location)
- Space constraints must be maintained
  - Beam pipe diameter must remain at 88mm
  - 60mm maximum jaw gap with 5mm center variation
- Central stop roller jaw adjust mechanism seems incompatible with 60mm gap, plus need to understand impact of having device in beam median plane
- Relatively simply geometry used to date in energy deposition studies (at SLAC) must be improved to true maximum heat load is understood
- Tests/simulations to estimate extent of damage in asy. beam abort should continue

Collaborative Discussions of Phase I Project

CERN will xfer latest version of tracking code with absorbers at 10sigma

SLAC will investigate thinner layers of Cu on appropriate substrates as well as revisiting exotic metals (SuperInvar, ALbuMet, GumMetal)

Eventual MARS benchmark of FLUKA results still deemed valuable

Phase II Infrastructure requirements are being frozen

- They will be transmitted to SLAC
- Will look into possibility integrating CERN mover system with SLAC jaw assembly

Politics

- CERN content with statement that Go/No-Go is “Go”
- SLAC must retool schedule so that RC2 (beam test prototype) arrives at CERN early 2008 in time for installation before prsumed May-Nov 2008 run
- Phase II collaboration meeting will be scheduled in June at SLAC with adequate CERN engineering and simulation expertise to ensure that RC1/RC2 specs meet LHC requirements and constraints
  - Later (September) would delay incorporation to design